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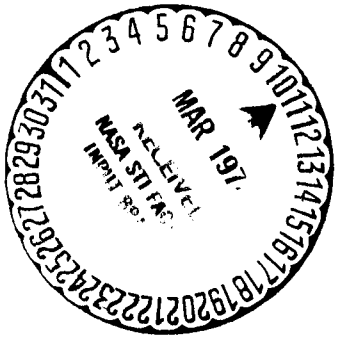
DEVELOPMENT OF HIGH STRENGTH TANTALUM BASE ALLOYS

Progress Report No. 6

Prepared By

R. L. Ammon



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PROGRESS REPORT NO. 6

DEVELOPMENT OF HIGH STRENGTH TANTALUM BASE ALLOYS

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Prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Period Covered: April 1, 1971 to June 30, 1971

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NASA-Lewis Research Center
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FOREWORD

This report was prepared by the Astronuclear Laboratory of the Westinghouse Electric Corporation under Contract NAS 3-12971. This work is administered under the direction of Mr. Paul Moorhead of the NASA-Lewis Research Center.

This work at the Astronuclear Laboratory is being administered by Mr. R. W. Buckman, Jr. Mr. R. L. Ammon is serving as the principal investigator. This report covers the work performed during the period April 1 to June 30, 1971.

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I. INTRODUCTION

This is the sixth progress report under Contract NAS 3-12971 covering activities from April 1 to June 30, 1971. The objective of this program was to select, melt and process to various mill shapes, two high strength tantalum base alloys for use in the 2000 to 3000°F temperature range. The two alloy compositions selected for this program were:

NASVF-1000 (Ta-12W-1.0Re-0.7Hf-0.025C) herein referred to as ASTAR-1211C
NASVF-2000 (Ta-15W-1.0Re-0.7Hf-0.025C) herein referred to as ASTAR-1511C.

The compositions were selected with the objective of achieving the highest creep and yield strengths, while maintaining a moderate degree of fabricability. The compositions were selected as a result of alloy studies conducted under Contracts NAS 3-2542 and NAS 3-10939.

The program is divided into five tasks. In Task I, two five inch diameter ingots of each alloy composition were melted and processed to round bar stock for use in the other four tasks. In Task II, small diameter swaged bar stock was produced for evaluation. In Task III, billets were processed to sheet for evaluation. In Task IV, material is being processed to tubing for evaluation. In Task V, forged discs were produced for evaluation.

II. PROGRAM STATUS

Task I - Melting and Processing of ASTAR-1211C and ASTAR-1511C

Task completed.

Task II - Processing and Evaluation of Swaged Bar Stock

The objective of this task is two-fold: (1) develop a thermal mechanical process for producing swaged bar stock with good mechanical properties; (2) generate tensile, creep and ductile-to-brittle transition temperature data for material produced by the above process. The process schedule for this task is outlined in Figure 1.

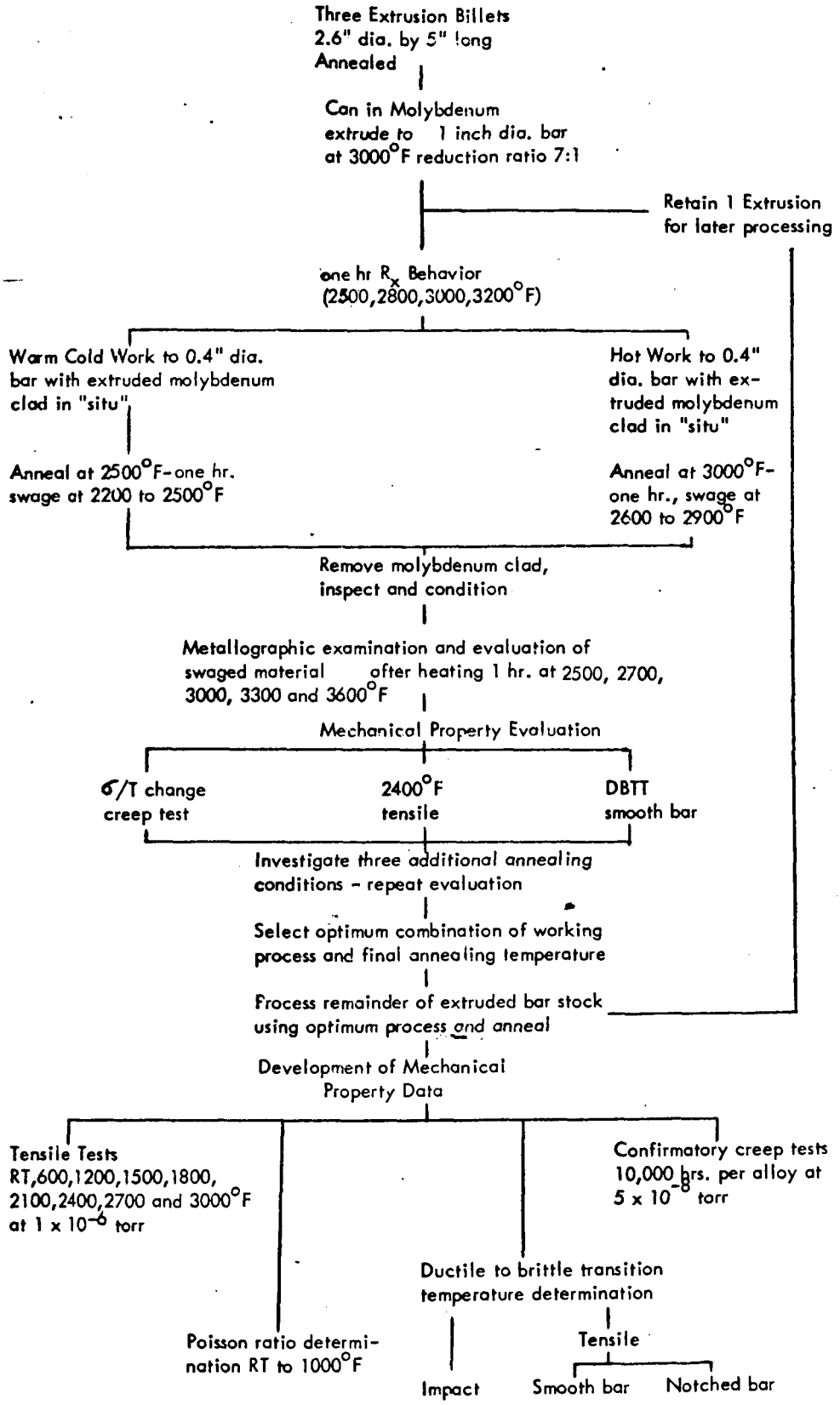


Figure 1. Schedule for Processing and Evaluation of Swaged Bar Material

During the report period, the evaluation of swaged rod produced under the first objective of this task was continued. Creep testing of ASTAR-1211C and ASTAR-1511C was continued. Three additional final annealing conditions for ASTAR-1211C swaged at 2500°F were selected. Low temperature tensile tests were conducted. Poissons ratio for both ASTAR-1211C and ASTAR-1511C was determined at room temperature and at 200°F increments up to 1600°F. Interstitial chemical analysis of finished rod stock was taken to check pick-up during processing.

CREEP TESTING

The creep evaluation program of ASTAR-1211C and ASTAR-1511C was continued during the report period. The status of creep testing for the initial evaluation is summarized in Table 1. All of the ASTAR-1211C rod swaged at 2500°F has been completed and previously reported[1,2]. All of the ASTAR-1211C rod swaged at 3000°F has been tested except for the material annealed at 2500°F which is currently under test. Five ASTAR-1511C creep tests were completed during the report period, two are currently in progress, and two remain to be tested. Data for tests completed during the report period and tests currently in progress are given in Table 2. In Figure 2 a Larson-Miller plot of all ASTAR-1211C data is shown. The time parameter in the Larson-Miller equation represents the time to 1 per cent creep strain. The testing method was described in a previous progress report[1]. One creep specimen was used for each final annealing condition. The time to 1 per cent strain was extrapolated from secondary creep rates in most cases. Where creep strain exceeded 1 per cent actual time was used. In no case was primary creep strain included due to the nature of the testing.

The ASTAR-1211C data reveal that prior thermal-mechanical processing as well as final annealing temperature exert a significant influence on creep behavior. The effects are illustrated more graphically in Figure 3. The data for this figure were taken from Larson-Miller plot in Figure 2. In this figure the stress required to produce 1% creep strain in 1000 hours is plotted as a function of final annealing temperature for material processed at the two swaging temperature. The open points which represent material swaged at 2500°F show an increase in stress with increasing final annealing temperature. A slight drop off at

Table 1. Creep Testing Status of Swaged ASTAR-1211C and ASTAR-1511C

Final Annealing Temperature	ASTAR-1211C Swaging Temperature		ASTAR-1511C Swaging Temperature	
	2500°F	3000°F	2500°F	3000°F
2500°F	C	⊗	TBT	TBT
2700°F	C	X	TBT	X
3000°F	C	C	X	X
3300°F	C	C	X	X
3600°F	C	C	⊗	⊗

C Test Completed and Results Previously Reported

X Test Completed During Past Report Period

⊗ Test Currently in Progress

TBT To be Tested

Table 2. Creep Data for ASTAR-1211C and ASTAR-1511C

Specimen Identification and Condition	Stress KSI	Test Temp (°F)	Strain on Loading (%)	Secondary Creep Strain (%)	Secondary Creep Time (hrs)	Secondary Creep Rate (%/hr)	Time to 1% Strain hrs	P $T_R°$ (15 + Log t) × 10^{-3}
1A12-27	40	2000	0.22	0.11	283	.00039	2570	45.3
ASTAR-1211C	30	2200	-	0.21	310	.00068	1472	48.3
Swaged at 3000°F	20	2400	-	0.14	195	.00072	1390	51.9
Annealed 1 hr/2700°F	15	2450	-	0.03	42	.00071	1400	52.8
	15	2500	-	0.57	330	.00173	578	52.6
1A12-25	40	2000	0.14	0.35	191	.00183	545	42.8
ASTAR-1211C			TEST IN PROGRESS					
Swaged at 3000°F								
Annealed 1 hr/2500°F								
2B41-30	40	2000	0.06	0.20	216	.00093	1080	44.4
ASTAR-1511C	30	2200	-	0.69	311	.00222	452	47.0
Swaged at 2500°F	20	2400	-	0.94	167	.00562	178	49.3
Annealed 1 hr/3000°F	15	2400	-	0.40	247	.00162	677	50.9
2B41-33	40	2000	0.19	0.26	211	.00162	620	43.8
ASTAR-1511C	30	2200	-	0.44	313	.00141	712	47.5
Swaged at 2500°F	20	2400	-	0.84	166	.00510	196	49.5
Annealed at 1 hr/3300°F	15	2400	-	0.77	266	.00289	346	50.2
2B11-27	40	2000	0.04	0.14	331	.00042	2360	45.3
ASTAR-1511C	30	2200	-	0.37	144	.00257	389	46.8
Swaged at 3000°F	20	2400	-	0.64	70	.00916	109	48.7
Annealed 1 hr/2700°F	15	2400	-	0.39	125	.00312	321	50.1
	12.5	2400	-	0.57	194	.00294	340	50.1
2B11-30	40	2000	0.19	0.09	376	.00024	4170	45.8
ASTAR-1511C	30	2200	-	0.20	216	.00092	1080	48.0
Swaged at 3000°F	20	2400	-	0.68	123	.00553	181	49.4
Annealed 1 hr/3000°F	15	2400	-	1.22	459	.00268	376	50.3
2B11-33	40	2000	0.21	0.12	282	.00042	2350	45.2
ASTAR-1511C	30	2200	-	0.39	311	.00125	800	47.6
Swaged at 3000°F	20	2400	-	0.68	148	.00458	218	49.6
Annealed 1 hr/3300°F	15	2400	-	0.52	247	.00211	475	50.6

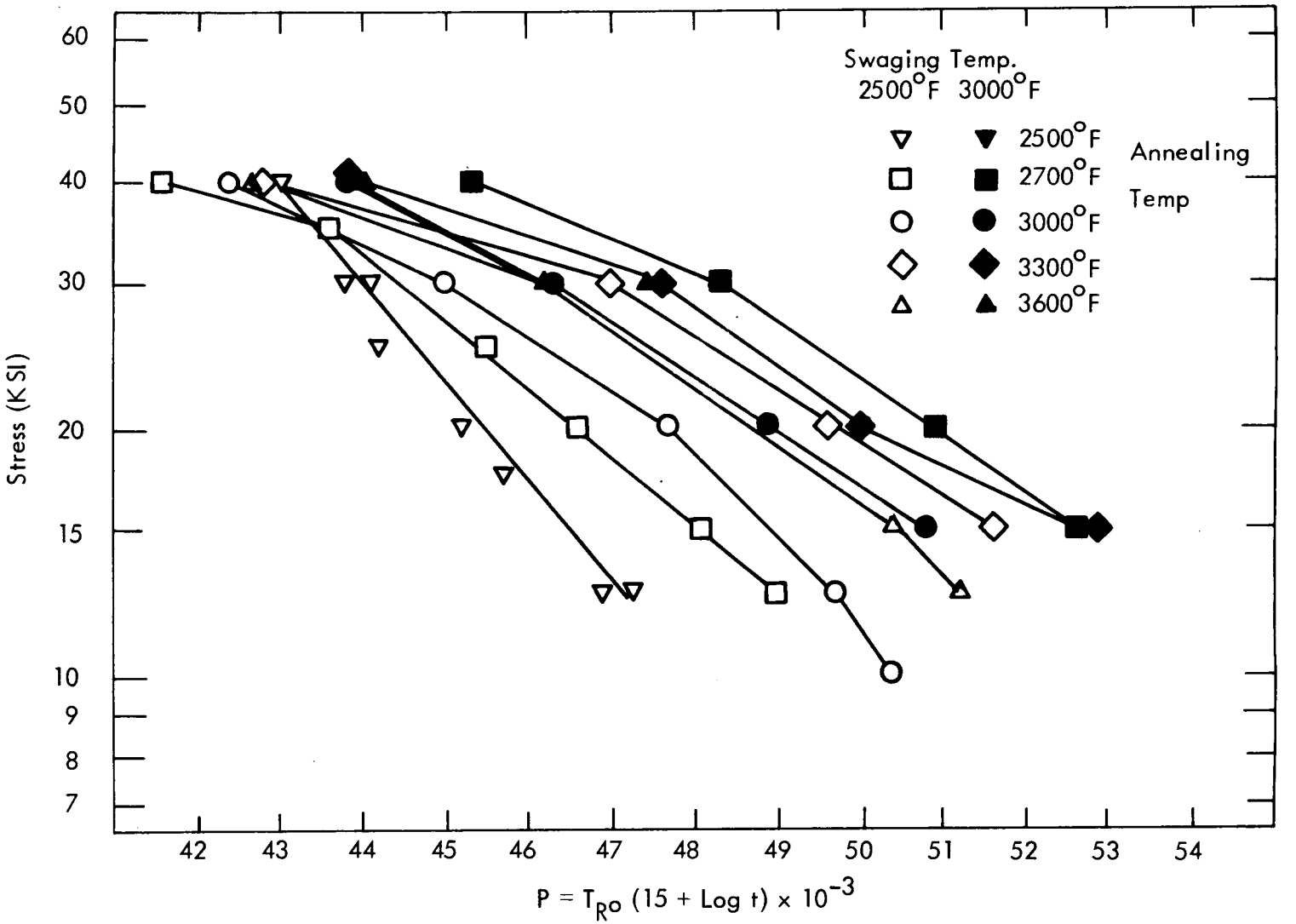


Figure 2. Creep Data for ASTAR-2111C Swaged Bar Stock

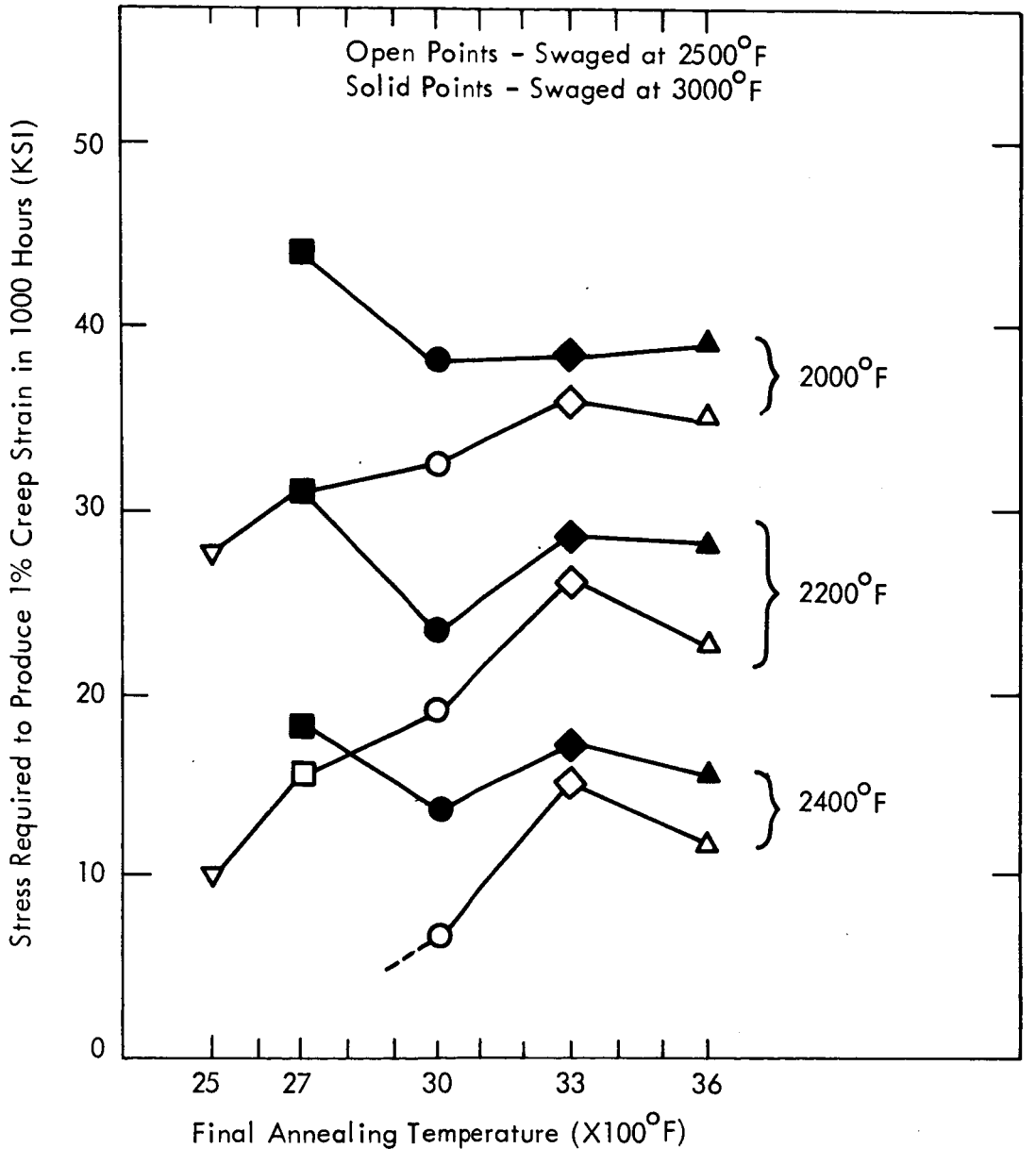


Figure 3. Stress to Produce 1 Percent Creep Strain in ASTAR-1211C as a Function of Processing and Final Annealing Temperature

3600°F is noted for each of the selected temperatures. The material processed and annealed at 2500°F and which had a wrought microstructure displayed the highest creep rate. The material undoubtedly was undergoing recrystallization during creep testing. It has been shown that when recrystallization occurs during creep testing an excellerated creep rate can be expected[3]. Of the final annealing temperatures investigated the 3300°F anneal appears to produce the best creep behavior.

The psuedo-hot worked material, swaged at 3000°F, exhibited comparable or better creep behavior for all the final annealing conditions compared to the warm worked material swaged at 2500°F. The material annealed at 2700°F displayed the best creep behavior of the four conditions evaluated so far. Initial results of material annealed at 2500°F indicate that creep behavior for this material will not match the 2700°F results. The reason for the anomalous creep behavior of the 2700°F annealed material is not known at this time. The 2400°F tensile data as well as the low temperature tensile results were not indicative of any major differences with respect to short time strength properties as a function of final annealing temperature.

The data for ASTAR-1511C are plotted in Figure 4. Unlike ASTAR-1211C, ASTAR-1511C creep behavior exhibits little or no sensitivity to swaging temperature or to final annealing temperature. The material swaged at 2500°F and annealed at 2500°F and 2700°F has a wrough or partially recrystallized microstructure. When tested, it is expected that ASTAR-1511C with those final anneals will exhibit creep behavior similar to the ASTAR-1211C with the same thermal mechanical history. Creep testing of the initial five final annealed conditions will be completed during the next report period.

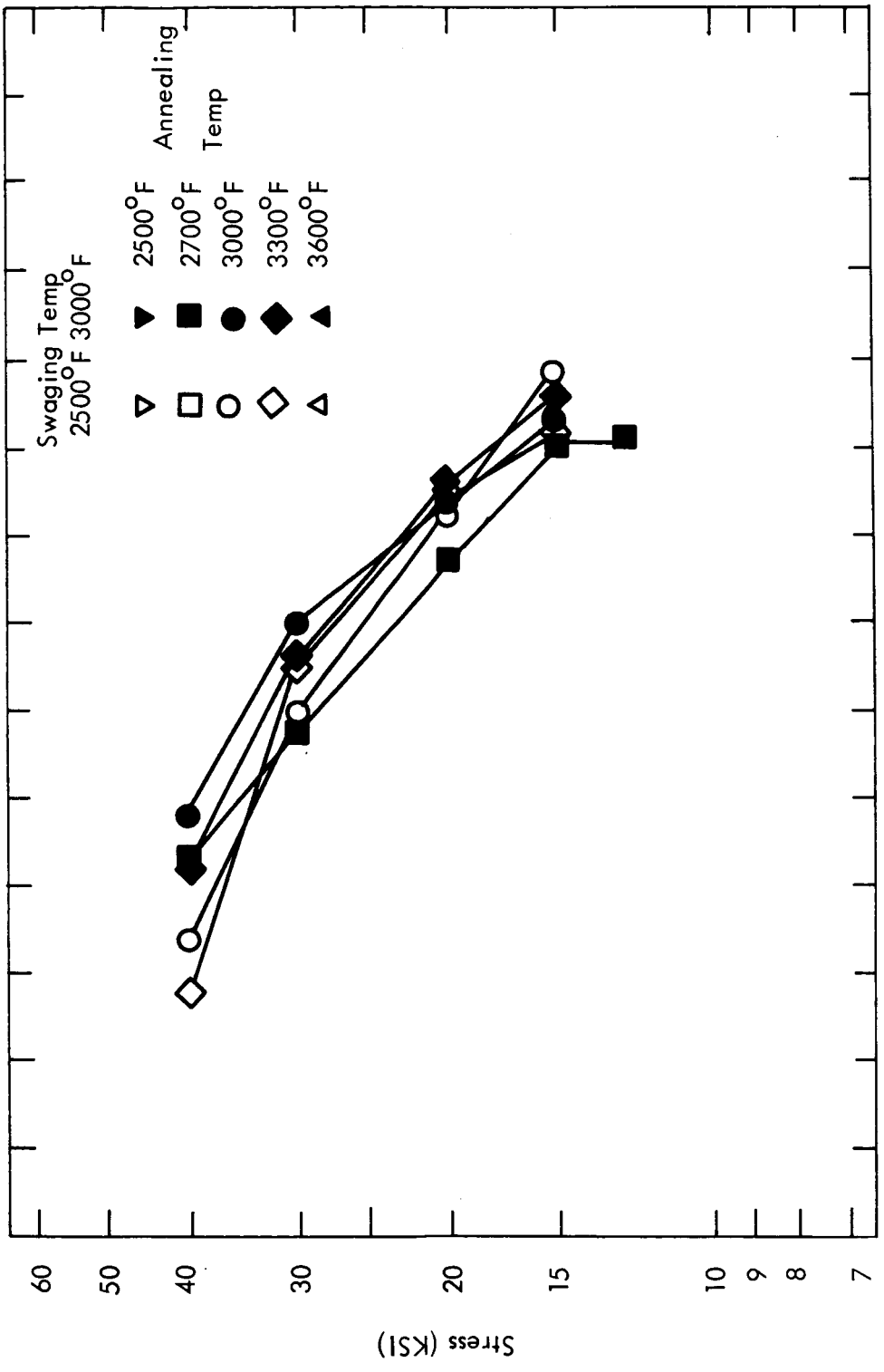


Figure 4. Creep Data for ASTAR-1511C Swaged Bar Stock

ADDITIONAL FINAL ANNEALING CONDITIONS FOR ASTAR-1211C

At the conclusion of creep testing of ASTAR-1211C swaged at 2500°F, three additional final annealing conditions were selected in accordance with program plan and, in concurrence with the NASA project management. The additional final annealing conditions selected were as follows:

1. One hour at 3200°F.
2. One hour at 3000°F followed by one hour at 2300°F.
3. One hour at 3300°F followed by one hour at 2300°F.

The first annealing condition - one hour at 3200°F - was selected to investigate the temperature range between 3000 and 3300°F. The material annealed at 3300°F exhibited the best creep resistance of the five annealing conditions investigated. The material annealed at temperatures of 3000°F and below displayed better low temperature ductility.[1] The intermediate temperature of 3200°F was selected to provide additional information concerning the effects of final annealing temperature on the low temperature ductility behavior and high temperature creep properties. The second two final annealing conditions were selected to investigate the effect of duplex heat treatments on low and high temperature mechanical properties. Duplex heat treatments have been shown to cause a significant reduction in room temperature hardness of ASTAR-1211C.[1]

Before test specimens were heat treated, samples of ASTAR-1211C rod swaged at 2500°F were annealed for one hour at 3300°F. Then samples were annealed at 2000, 2200, 2300 and 2500°F. Room temperature hardness measurements were taken to determine the hardness minima as a function of the secondary annealing temperature. The hardness data are given in the following table.

Table 3. RT Hardness of Duplex Heat Treated ASTAR-1211C Swaged Rod

Secondary Annealing Temperature	Primary Annealing Temperature 3300°F	3300°F
2000°F	298	298
2200°F	---	288
2300°F	276	283
2500°F	285	285

As a result of the hardness study, the one hour anneal at 2300°F was confirmed as the secondary heat treatment for both duplex heat treatments.

Four tensile specimens and one creep specimen of ASTAR-1211C rod material swaged at 2500°F were given final heat treatments for each of the final annealing conditions listed. During the report period, low temperature and 2400°F tensile testing were completed. Results are listed in Table 4. Room temperature tensile data are plotted in Figure 5 along with data for the initial fine final annealing conditions. The yield and ultimate strengths of the 3200°F annealed material were unexpectedly lower than the 3000 and 3300°F annealed material. The yield and ultimate strengths of the duplex annealed material were lower as expected. The total elongation values of the three additional test conditions were similar and comparable to values for the five prior test conditions.

Sub-room temperature total elongation and reduction in area data for the three additional test conditions are plotted in Figures 6 and 7 along with data for the prior five test conditions. The total elongation and the reduction in area for the material annealed at 3200°F fall between the 3000 and 3300°F data as expected. The results for the duplex annealed material were not as predictable. The material anneal at 3000/2300°F exhibited improved low temperature ductility behavior over the single 3000°F annealed material while the 3300/2300°F condition produced a significant increase in the ductile-to-brittle transition temperature. The microstructures of material in the three additional test conditions are shown in Figure 8. The photomicrographs were taken of the head section of room temperature tensile specimens.

Table 4. Tensile Properties of ASTAR-1211C Rod Swaged at 2500°F and Given Various Heat Treatments

Final Heat Treatment	Test Temperature (°F)	Yield Strength (KSI)	Ultimate Strength (KSI)	Elongation Uniform (%)	Elongation Total (%)	Reduction in Area (%)
1 hr/3200°F	RT	103.6	126.0	17.9	21.3	54.2
	- 100	125.4	146.0	16.3	18.5	41.3
	- 200	138.7	156.2	11.8	11.8	16.0
	2400	42.1	55.2	7.6	23.6	68.2
1 hr/3000°F	RT	99.5	116.2	21.6	26.0	62.2
+	- 100	117.7	134.3	18.8	22.4	51.0
1 hr/2300°F	- 200	129.0	144.0	13.4	16.1	51.2
	2400	36.9	50.4	11.9	45.4	79.0
1 hr/3300°F	RT	93.6	112.5	19.9	22.9	49.1
+	- 50	116.9	126.3	6.2	6.2	4.9
1 hr/2300°F	- 10	110.2	121.3	6.1	6.1	5.2
	2400	33.2	46.6	10.8	31.0	56.2

Strain Rate 0.05/Min.

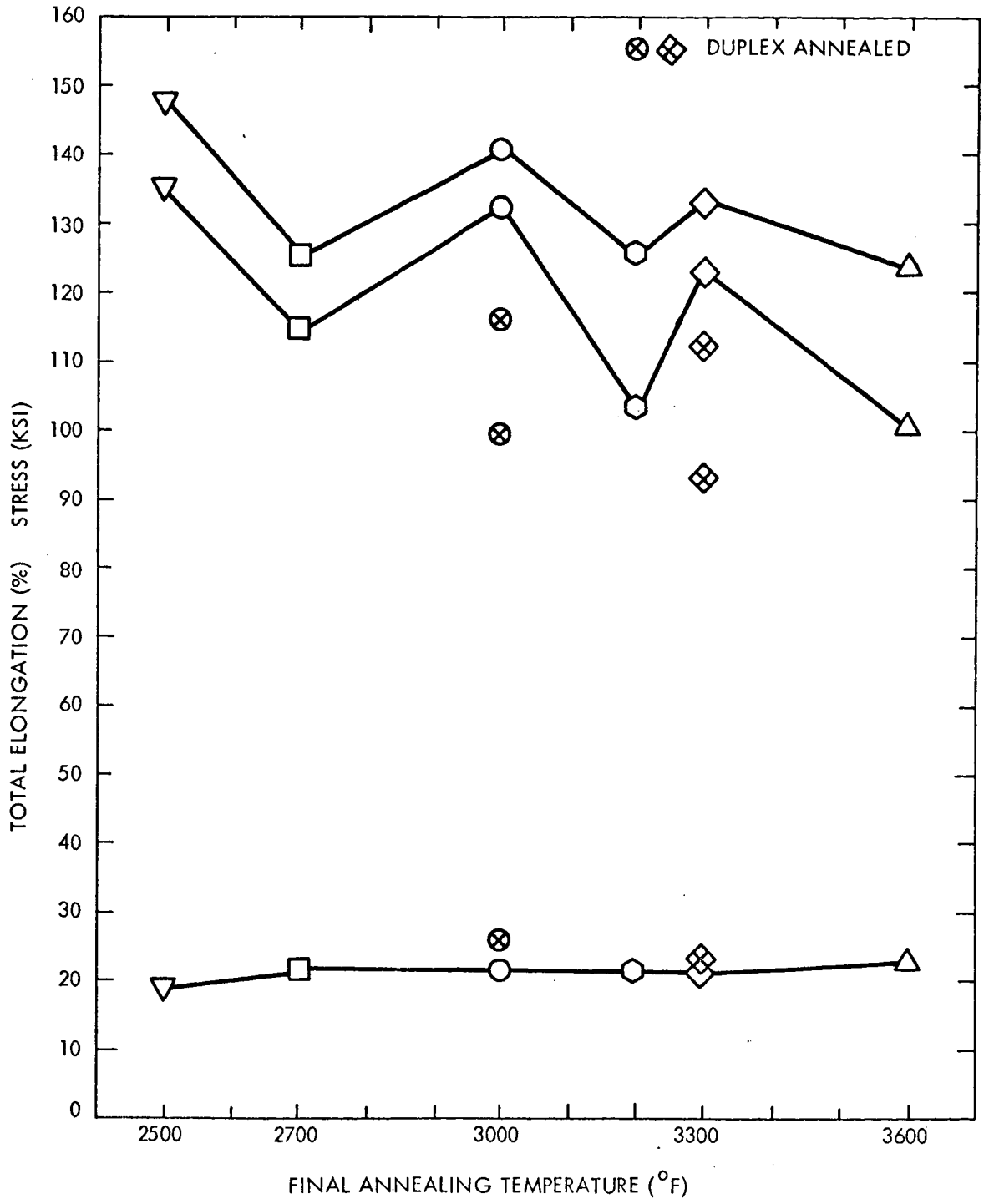


Figure 5. Room Temperature Tensile Properties of ASTAR-1211C Swaged at 2500°F and Annealed at Various Temperatures

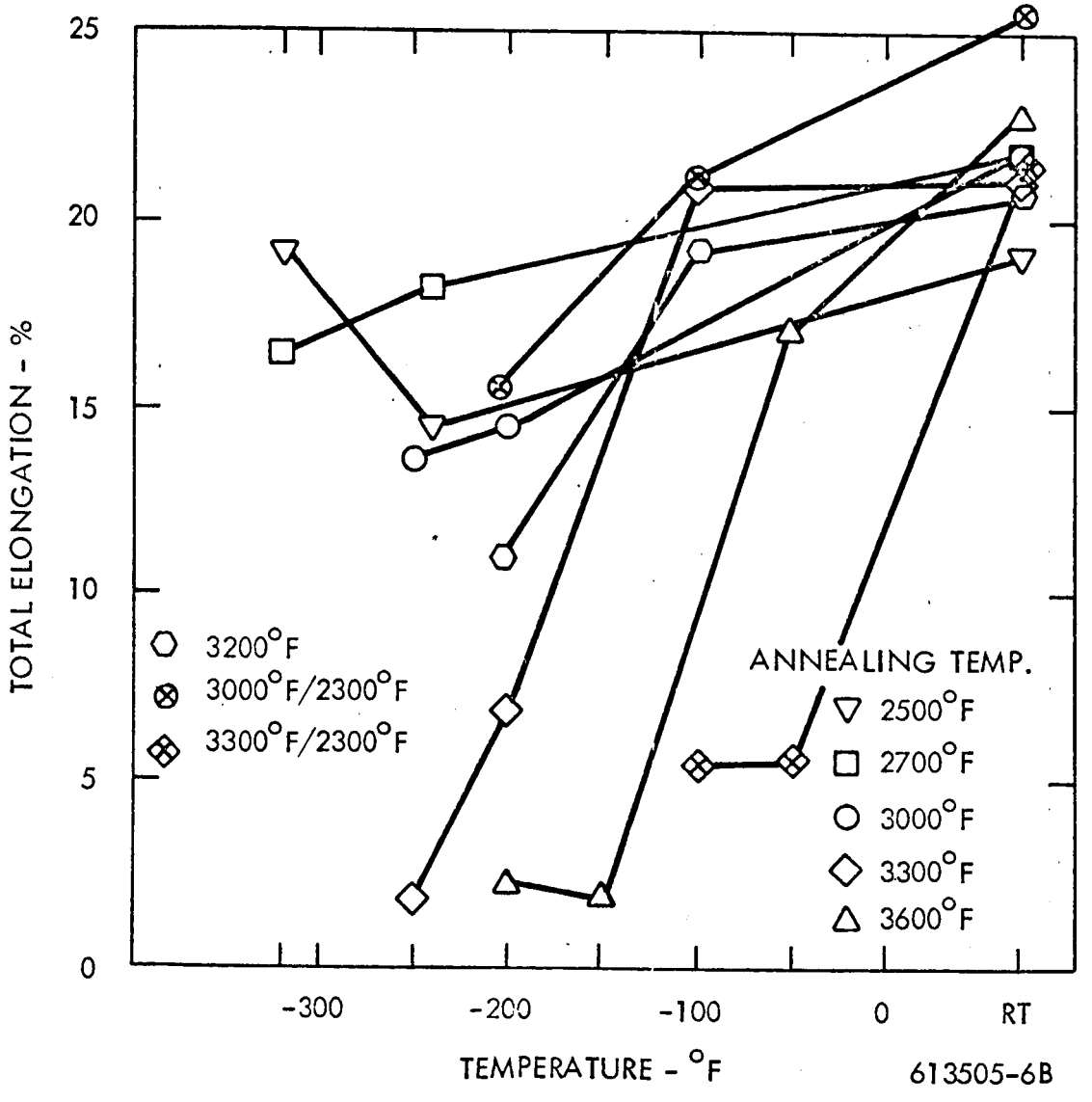


Figure 6. Low Temperature Tensile Elongation of ASTAR-1211C Swaged at 2500°F

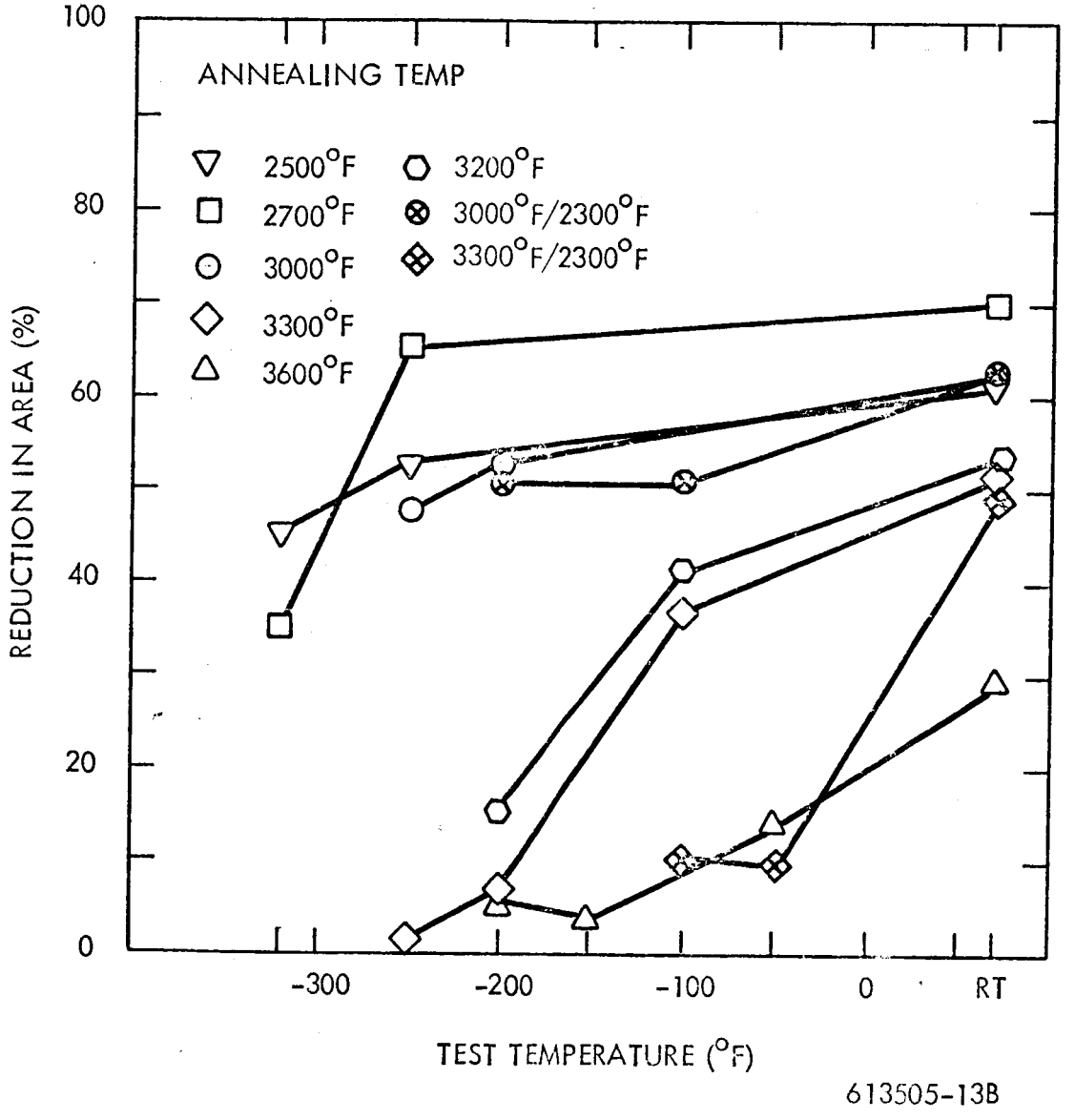
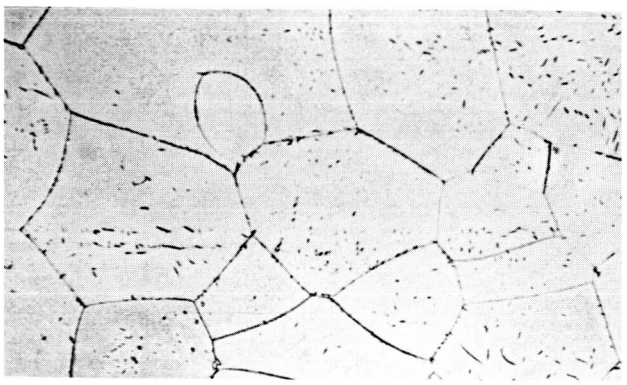
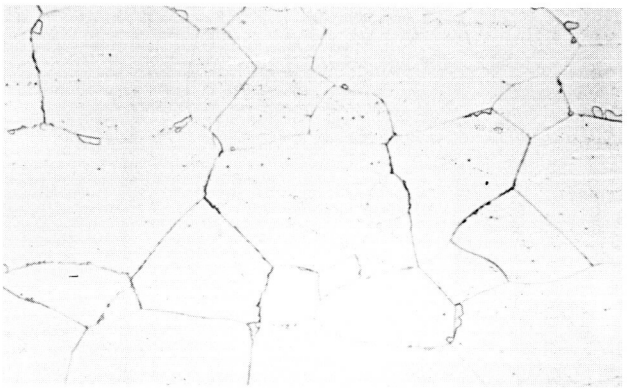


Figure 7. Reduction in Area of ASTAR-1211C Swaged at 2500°F at Low Temperatures



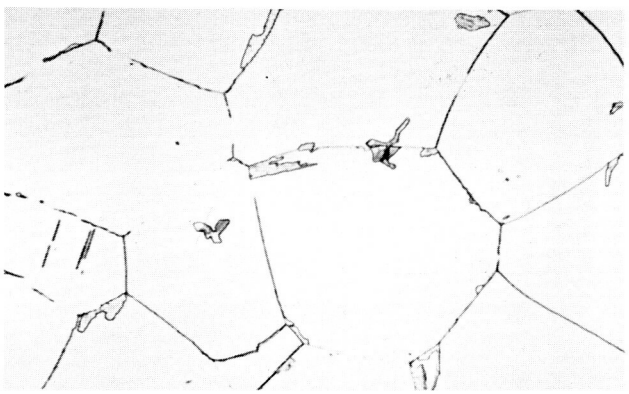
ASTAR-1211C
Swaged at 2500°F
Annealed 1 hr/3200°F

500X DPH 308



ASTAR-1211C
Swaged at 2500°F
Annealed 1 hr/3000°F +
1 hr at 2300°F

500X DPH 271



ASTAR-1211C
Swaged at 2500°F
Annealed 1 hr/3300°F +
1 hr at 2300°F

500X DPH 280

Figure 8. Microstructure of ASTAR-1211C Swaged at 2500°F and Annealed at Various Temperatures

The 3200°F annealed material exhibited a microstructure similar to 3600°F annealed material previously reported.[1] Both the grain-boundary and the grain matrix were decorated with a fine precipitate which appears to have precipitated during cooling. The duplex annealed material exhibited a fairly clean matrix with the large discontinuous precipitate confined to the grain boundary. It appears that the fine precipitate did not form in the matrix, or if it did, redissolved and reprecipitated on the more stable grain boundary precipitate. The room temperature hardness of the duplex annealed material is approximately 10 per cent lower than the single annealed material. This difference is consistent with previous results.[2] The large grain boundary precipitate which has been identified as the hexagonal Ta_2C phase is responsible for the removal of carbon from the matrix and thus the lowering of room temperature hardness.[4]

The 2400°F tensile data are plotted in Figure 9 along with data for the five initial final annealed conditions. The strength properties of the 3200°F annealed material falls within a reasonable scatter band with respect to the strength of the five initial annealed conditions. The strength properties of the duplex annealed material show a trend to lower values. Considering that the 2300°F secondary annealing temperature was below the actual test temperature, a significant difference in mechanical properties would not be expected unless a time dependent structural change was occurring within the alloy during the secondary anneal. Metallographically, it has been noted that massive carbides at the grain boundary are promoted during such a heat treatment. These results could be interpreted as evidence that the disposition of carbon in these alloys has a significant effect on short time mechanical properties at temperatures as high as 2400°F.

CHECK CHEMICAL ANALYSIS

Interstitial chemical analysis were taken of random samples of finished or nearly finished mill products to check pick-up during processing. The results are listed in Table 5. The swaged rod samples were taken from material in the "as swaged" condition. The rod material was swaged out of a hydrogen furnace for both swaging temperatures, thus the high hydrogen

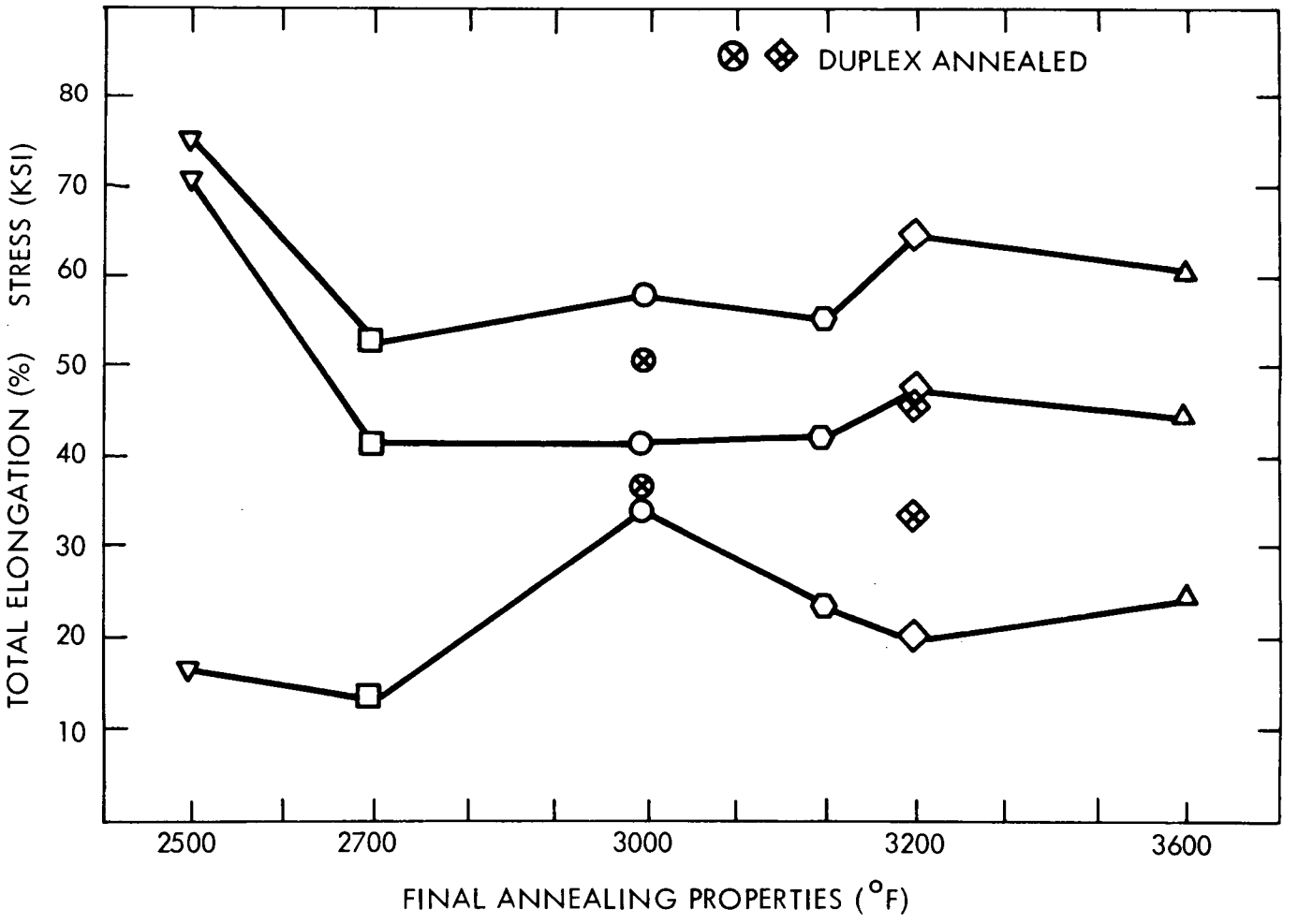


Figure 9. 2400°F Tensile Properties of ASTAR-1211C Swaged at 2500°F and Annealed at Various Temperatures

Table 5. Interstitial Chemical Analysis of ASTAR-1211C and ASTAR-1511C

Sample Identification	Chemical Analysis (PPM) N_2	O_2	H_2	C
ASTAR-1211C Rod Swaged at 2500°F	12	17	37	260
ASTAR-1211C Rod Swaged at 3000°F	21	48	31	240
ASTAR-1511C Rod Swaged at 2500°F	13	27	27	250
ASTAR-1511C Rod Swaged at 3000°F	11	23	36	190
ASTAR-1211C Forged Disc	11	10	0.7	230
ASTAR-1511C Forged Disc	12	7	17	230
ASTAR-1211C Tube Blank	13	5	0.2	280
ASTAR-1511C Tube Blank	11	8	0.2	230
ASTAR-1211C - 0.040 Inch Sheet	11	8	0.2	260
ASTAR-1511C - 0.040 Inch Sheet	12	45	0.4	190

in this material. Samples have been vacuum annealed and are currently being analyzed to determine the degree of hydrogen removal by subsequent heat treatment. It is expected that essentially all the hydrogen is removed during a high temperature vacuum anneal. The ASTAR-1511C forged disc also had a high hydrogen level which was traced to the method of chemically removing the protective molybdenum clad applied prior to forging. In the case of the forged ASTAR-1211C, nitric acid was used to remove the molybdenum clad and as noted little or no hydrogen was picked up. The ASTAR-1511C forging was inadvertently pickled with a solution containing nitric acid and hydrofluoric acid. The resultant exothermic reaction and the availability of nacent hydrogen from the chemical reaction is believed to have been responsible for the high hydrogen in this material. The sheet material which was processed at low temperatures and the tube blanks which were processed in a routine manner show a normal spread in interstitial levels.

Determination of Shear and Young's Modulii and Poisson's Ratio

Under the second objective of this task, as shown in Figure 1, the determination of Poisson's ratio in the temperature range of room temperature to 1600° in 200°F increments is required. The determination of the elastic properties of ASTAR-1211C and ASTAR-1511C was conducted by Panametric a subsidiary of Esterline Corporation of Waltham, Massachusetts. The determinations were made using an ultrasonic thin-line technique developed by Panametrics.[5] Recrystallized samples 1/8 inch in diameter by three inches long were used. Elevated temperature tests were conducted in vacua. Results are given in Table 6. Poisson's ratio for both alloys appears to be constant over the temperature range of the evaluation. The ASTAR-1511C had a slightly lower ratio compared to ASTAR-1211C. The higher tungsten, about 3 per cent, in ASTAR-1511C is most likely responsible for the difference in elastic properties of the two alloys.

Task III - Processing and Evaluation of Sheet

The evaluation of sheet under this task consists primarily of the investigation of the effect of EB and GTA welds on ductile-brittle transition behavior. The initial testing which was completed during the prior report period involved evaluation of the tensile and bend

Table 6. Elastic Properties of ASTAR-1211C and ASTAR-1511C

Temperature °F	Young's Modulus E x 10^6 PSI	Shear Modulus G x 10^6 PSI	Poisson's Ratio
	ASTAR-1211C		
RT	28.42	10.82	0.313
200	28.30	10.72	0.319
407	27.98	10.63	0.316
598	27.80	10.54	0.318
821	27.55	10.44	0.319
1010	27.37	10.37	0.319
1204	27.13	10.28	0.319
1405	26.83	10.22	0.312
1609	26.66	10.16	0.312
	ASTAR-1511C		
RT	28.85	11.13	0.296
179	28.72	11.03	0.302
376	28.47	10.97	0.297
570	28.28	10.91	0.296
791	28.03	10.83	0.294
980	27.83	10.74	0.295
1175	27.67	10.66	0.298
1374	27.49	10.57	0.300
1576	27.30	10.51	0.298

ductile-to-brittle behavior of EB and GTA welded ASTAR-1211C sheet. The evaluation of ASTAR-1511C sheet was limited to the characterization of the behavior of EB and GTA welded sheet in the bending mode only. In the initial investigation welded material was tested in the "as-weld" and post-weld annealed condition. The final portion of this program involves the testing of welded, post weld annealed and thermally aged material. Additional sheet material of both alloys was required. During the past report period, one additional billet of each composition was committed to the sheet evaluation program. ASTAR-1211C billet NASVF-1000-B-3 and ASTAR-1511C billet NASVF-2000-A-2 were encapsulated in molybdenum and extruded at 3000°F to a sheet bar configuration. The extrusions were cut into segments and forged to plate. The conditioned plates were processed to sheet using the procedures developed earlier for each alloy composition.[1] The finished sheet was cut to approximate size for GTA welding and given a one hour anneal at 3000°F. Both longitudinal and transverse welded tensile specimens were made from the ASTAR-1211C sheet. Only longitudinal GTA weld specimens of the ASTAR-1511C sheet will be evaluated. The tensile specimens containing the GTA welds are currently being given post weld anneals at 3000, 3300, and 3600°F. Prior to testing the tensile specimens will be thermally aged for 1000 hours at 2100, 2400, and 2600°F.

Task IV - Processing and Evaluation of Tubing

The objective of this task is to attempt to make and evaluate nominal 0.750 inch OD by 0.040 inch wall tubing. In the prior report period, two ASTAR-1211C tube blanks were successfully drawn while attempts to "point" or "tag" the ASTAR-1511C proved unsuccessful. During the past report period, effort was concentrated on "pointing" the ASTAR-1211C tube for the second drawing pass and preparing the ASTAR-1511C tube for the first drawing pass.

The purpose of the "point" or "tag" on the tube blank is to provide a grip on the tube ID to enable the mandrel to pull the tube blank through the die. For normally ductile materials the "tag" is made by a simple swaging operation. The swaging of ASTAR-1211C for the first drawing was marginally successful. The "tag" on both ASTAR-1211C tube blanks were cracked

prior to drawing and broke off completely during the drawing process. Attempts to swage a "point" on the ASTAR-1511C tube blanks at 800°F, were completely unsuccessful. The material cracked and broke off after only a slight reduction. After consultation with Superior Tube, the OD of all the ASTAR-1211C tube blanks and one ASTAR-1511C blank were machined to a nominal 1 inch diameter and the ID was machined to give a 1/8 inch wall thickness. It was believed that the smaller wall thickness might be more amenable to swaging. The ASTAR-1211C tube blanks were annealed one hour at 3000°F followed by one hour at 2300°F. The results of an attempt to swage one of the shorter ASTAR-1211C tube blanks at 800°F is shown in Figure 10. The failure is typical of the results of attempts to swage point ASTAR-1511C. It was concluded that pointing by swaging at temperatures in the range of 600 to 800°F was unsatisfactory for these particular alloys. Another approach which offered possibilities of success was hydrostatic extrusion. This process has been used successfully to deform brittle materials at ambient temperatures. Facilities for carrying out such an operation were available at the NASA-Lewis Research Center. It was decided that one small ASTAR-1211C tube hollow could be used to evaluate the hydrostatic deformation process as a means for "pointing" the tube blanks. The details of the operation of the NASA facility are given in a NASA Technical Note.[6] The tube blank was fitted with a mild steel mandrel to provide support at the tube blank ID and to provide a seal for retention of the working fluid. The objective was to push 1/2 to 3/4 of inch of the tube blank into a conical shaped die. A die with a 40 degree included inlet angle was available and was used as a matter of convenience. The demonstration was quite successful and achieved what appeared to be a sufficient reduction in the first 1/2 inch of the tube. The remaining large ASTAR-1211C and the machined ASTAR-1511C were also processed in the same manner as the test piece. The results of the hydrostatic "pointing" operation are shown in Figure 11. The tube blanks were etched and dye penetrant inspected prior to shipment to Superior Tube for warm drawn. The dye penetrant inspection revealed that the ASTAR-1511C tube contained a circumferential crack just below the "pointed" or reduced end. The crack is not evident in the photograph of Figure 11. It is suspected that the crack may have formed during the etching process. There is not direct evidence to this effect, however. In light of this development, only the ASTAR-1211C tube blnak was sent to Superior Tube for warm drawing.

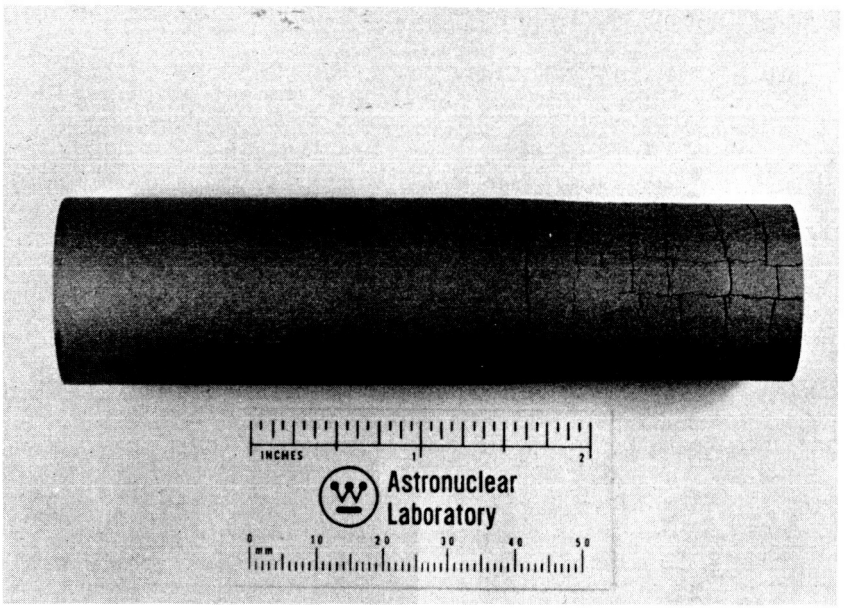


Figure 10. ASTAR-1211C Tube Blank which Failed During Swaging

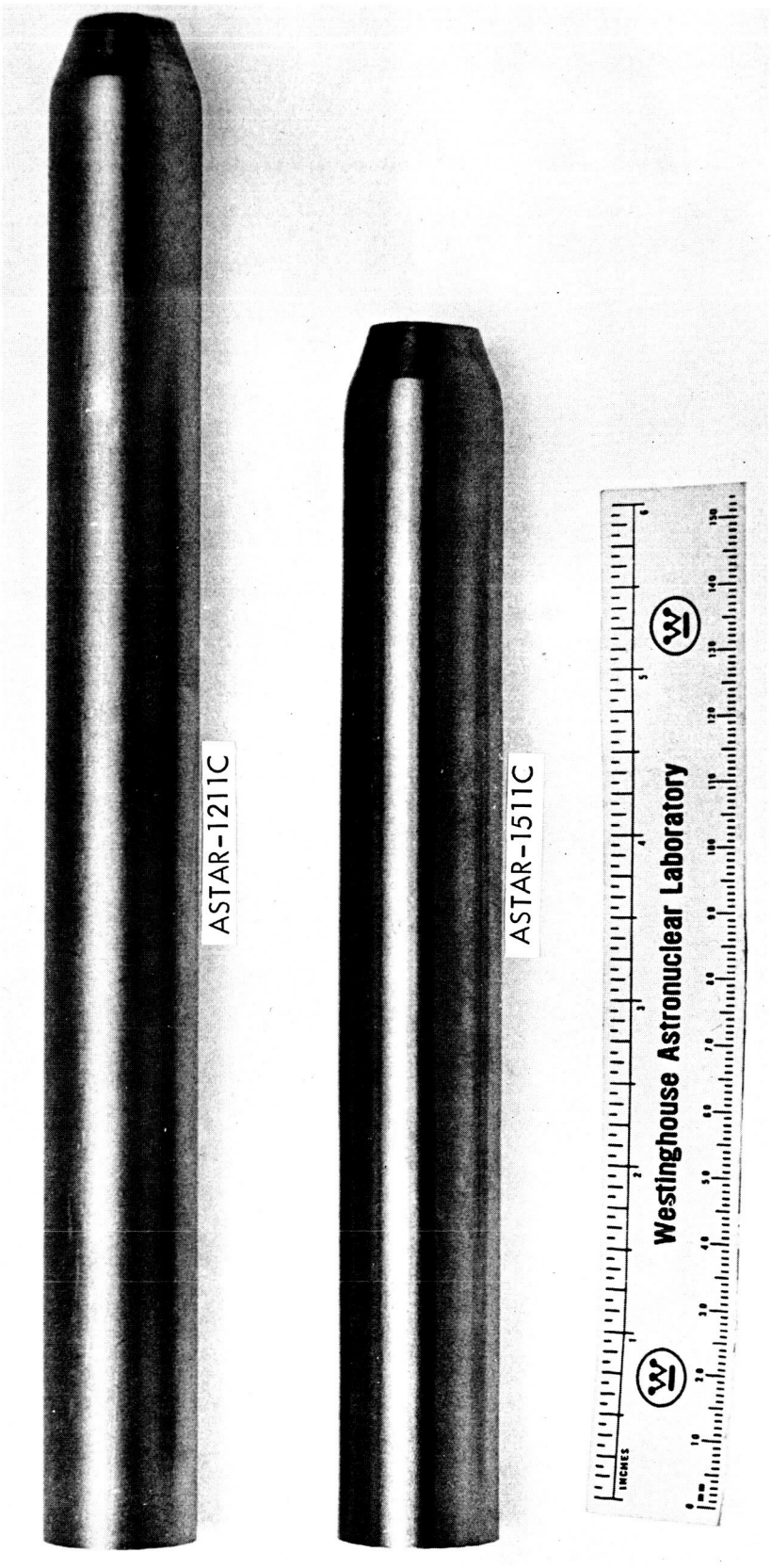


Figure 11. ASTAR-1211C and ASTAR-1511C Tube Blanks Pointed by Hydrostatic Extrusion

Task V - Processing and Evaluation of Forged Discs

The objective of this task is to evaluate the forgeability and obtain mechanical property data for ASTAR-1211C and ASTAR-1511C. Three billets of each composition were upset forged to round discs. The tensile testing of both alloys has been completed and results were reported in the previous progress report. Only the creep tests remain to be completed under this task.

Creep testing of forged ASTAR-1211C continued during the report period. Results are listed in Table 7. Stress and temperature levels for this series of creep tests were selected from the Larson-Miller plot of ASTAR-1211C swaged bar stock annealed one hour at 3000°F (See Figure 2). The temperatures selected for the 20 and 15 KSI test specimens were too low. In both cases the temperatures had to be raised 200°F in order to produce detectable creep. A comparison of Larson-Miller parameters for material annealed at 3000°F in Figure 2 (data for forged material are not plotted) indicates that the forged material has significantly better creep resistance than the swaged bar material. It must be remembered that the swaged bar data are for multi-load; multi-temperature test conditions while the forged discs data are essentially single load, single temperature tests. Prior experience has shown that multi-load, multi-temperature test conditions tend to produce conservative creep results.

III. PROBLEM AREA

There are no major problem areas at this time. Creep testing under Task II continues to require more time than originally scheduled for the screening phase of the program.

IV. FUTURE WORK

Task I - Completed.

Task II - Creep testing of ASTAR-1211C and ASTAR-1511C will continue during the next period. The additional final annealing conditions for ASTAR-1211C material swaged at 3000°F and for ASTAR-1511C will be selected. Low temperature tensile testing of heated treated specimens of the selected additional annealed conditions will be completed.

Table 7. Creep Data for Forged ASTAR-1211C

Load (KSI)	Test Temperature (^{o}F)	Strain on Loading (%)	Secondary Creep Strain (%)	Secondary Creep Time (hrs)	Creep Rate (%/hr)	Time to 1% Strain (hrs)	P (1)
40	2000	0.25	2.65(2)	830(2)	(2)	360	43.2
30	2100	0.15	0.45	1001	0.00045	2250	46.9
20	2200	0.04	(3)	502	(3)	--	--
20	2300	--	(3)	167	(3)	--	--
20	2400	--	1.09	209	0.00522	192	49.5
15	2300	0.07	(3)	432	(3)	--	--
15	2400	--	(3)	163	(3)	--	--
15	2500	--	0.30	210	0.00143	700	52.8

(1) $P = T_{R}o\ (15 + \text{Log}\ t) \times 10^{-3}$

(2) No secondary creep rate established - time to 1% strain taken from creep curve.

(3) No detectable strain - temperature was increased.

Task III - The 1000 hour thermal aging of post-weld annealed low temperature tensile specimens of ASTAR-1211C and ASTAR-1511C sheet will be in progress at the end of the next report period.

Task IV - The attempt to produce ASTAR-1211C tubing will continue during the next report period. The hydrostatically "pointed" tube blank will be forwarded to Superior Tube for warm drawing.

Task V - Creep testing of forged ASTAR-1211C will be completed during the next report period and testing of ASTAR-1511C will be initiated.

V. REFERENCES

(1) R. L. Ammon, "Development of High Strength Tantalum Base Alloys," Progress Report No. 4, WANL-PR-NNN-004, January 31, 1971.

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(3) R. L. Ammon and R. T. Begley, "Pilot Production and Evaluation of Tantalum Alloy Sheet," Summary Phase Report, Bureau of Naval Weapons, Contract NOw 62-0656-d, June 15, 1963.

(4) R. W. Buckman and R. C. Goodspeed, "Development of Precipitation Strengthened Tantalum Base Alloys," WANL-PR(Q)-017.

(5) K. A. Fowler, "A New Way to Measure Elastic Modulii," Metals Progress Vol. 95, No. 6, June 1969.

(6) C. P. Blankenship, "Some Effects of Cold Working by Hydrostatic Extrusion on Mechanical Properties of High-Strength Steels," NASA-TN-D-6186, February 1971.